Design of object identification system based on machine vision

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in

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by

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Certificate

The work in the thesis entitled **Design of object identification system based on machine vision** by Pranesh Dahal, with roll number 111ME0525 is a bona fide work of research done under my supervision, direction and guidance in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering. Neither this thesis nor any part of it has been submitted for any degree or scholastic grant somewhere else.

(J.SRINIVAS)
Research supervisor

Abstract

Object sorting is an important aspect in almost all the industries. Production industries like food, chemical, petroleum and textile industries have to sort objects on numerous parameters. Various automated object sorting systems are required to avoid human flaws, with increase in productivity and reduce the overall time. Objective of the present work is to develop a part identification system using machine vision. Due to the advantage of LabVIEW in controlling hardware effectively it is employed in the present work. The Vision camera once identifies an object based on its attributes like color shape and size, immediately a signal should be communicated with the controller for separating that object. In this work the signal is shown as a glowing LED. Also the number of objects of particular category passing on the conveyor is counted and displayed to illustrate moving objects identification. A low speed conveyor belt is fabricated with different test objects passing over it. For identifying colors, wavelength data is used, for identifying the shape geometric pattern matching is used and for identifying the size edge detection is applied. The developed G-programming environment generates a graphic user interface in front panel. Ability to count the objects of specific attribute is tested for different trail runs. Thesis is organized as follows: Chapter 1 contains introduction to machine vision system, its components, the objectives of present study and literature review of similar works. Chapter 2 deals with various methods used in vision and their implementation in LabVIEW as done in this work was presented in chapter 3. Chapter 4 gives brief conclusions and future scope of present work.

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Contents

Chapter 1

INTRODUCTION

1.1 Overview

Machine vision provides the computer eyes and ears. Eyes are the most critical organs in the human body and our aptitudes depend to a great extent on our capacity to see, distinguish and separate between articles. Most occupations rely on upon our capacity of sight. Machine vision does not mean design and outlining; really, it is identified with the innovation of vision in manufactured sense. Cameras give PCs or gadgets the capacity to see and distinguish and recognize items or circumstances and to settle on the right choices in like manner. The study and advancement of strategies and methods that permits machines to translate computerized pictures in m/c vision.

Machine vision alludes the mechanical use of vision innovation. It portrays the understanding of actually acquired pictures for controlling creation forms. In the previous couple of years, it has formed into one of the key innovations in mechanical computerization, which is utilized as a part of every single assembling industries. Once in a while the term machine vision is additionally utilized for alluding non-mechanical applications. A viable vision framework must depict the scene precisely with doable handling time like in biometric example acknowledgment.

A machine vision framework comprises of a few vital segments, from the sensor (camera) that catches a photo for examination, to the processing engine itself (vision apparatus) that renders and conveys the outcome. Alternately any machine vision structure to work reliably and produce awesome results, it is key to grasp the coordinated efforts of these sections.

Here are a few examples for machine vision applications:

- Paper checking in production industries for errors.
- Making sure the syringes are made properly.
- Finding flaws in flat glass.
- Guiding robots for changing their positions
- Reading license plate numbers in vehicles
- Recognizing and identifying persons.
- Reading bar codes on different products

Amid the most recent 15 years, machine vision innovation has enhanced rapidly, getting to be imperative and much of the time, essential apparatus for assembling robotization. Today, machine vision applications are available in numerous commercial enterprises, including semiconductor, pharmaceuticals, bundling, gadgets, car and shopper products.

Generally, machine vision has been exceptionally fruitful in applications where it was coordinated into the creation process. Case in point, managing machines or shutting a control circle. Yet, while vision direction has demonstrated its worth in setting surface-mount segments on printed circuit sheets, most clients would dither before putting resources into a machine vision examination station to catch deficient parts on a current generation line. Nonetheless, persistent enhancements in expense, execution, algorithmic power and convenience have energized vision frameworks' utilization by and large assembling robotization. Further advances in these regions will bring about more vision frameworks on assembling floors amid the following couple of years.

Use of machine vision for object separation is not an unknown concept. Detecting objects on transportation is very common industrial problem. Model based recognition methods can be employed if all the objects are same or with few differences. In recycling plants, bottles, plastics and other materials require sorting. To inspect the objects stationary camera mounted above the conveyer belt system is used. One has to decide whether a pixel belongs to an object or to the background.

1.2 Components of machine vision

A camera and vision software are essential with many other components in a machine vision system. Illumination is very important component of machine vision. For the camera to capture images in a proper way a light source must be provided. If light is not proper object's parameters like color, length , area, shape, etc may be interpreted incorrectly by the vision system and hence after image processing the output may be the undesired one. Thus a proper light source is kept to provide luminance to the vision system. LED lamps are much preferred. Other light sources can also be used. Right intensity and correct direction of light is required.

Cameras are the eye of the machine vision system. The capture the images and send it to the computer system for processing. Various types of cameras can be used in a machine vision system according to the requirement. A charge coupled device (CCD) is an integrated circuit scratched onto a silicon surface framing light sensitive components called pixels. Photons striking on this surface create charge that can be perused by electronic circuits and transformed into an advanced duplicate of the light examples falling on the gadget. Photons striking a silicon surface create free electrons as well as holes through the photoelectric effect. If nothing else is done the hole and the electron will recombine and release energy in the form of heat. Small thermal fluctuations are very difficult to measure and it is thus preferable to gather electrons in the place they were generated and count them in some manner to create an image. This is accomplished by positively biasing discrete areas to attract electrons generated while the photons come onto the surface. Other types of cameras include line scan camera and CMOS camera.

Extent to which a camera can view the real world image in a time instant is known as field of view. After image acquisition, a number of processing steps are to be done on the images so that the image can be analyzed. Removing noises by filtering, controlling brightness, contrasts, sharpness, converting into binary images, etc are various ways of processing the image. For example, in case of edge detection, the image to be analyzed must be an 8 bit image. Thus from a 32 bit RGB image acquired by the camera, the RGB plane is extracted to convert it into an 8 bit image. Similarly, pixel counting is most common image processing method. It involves counting of light or dark pixels in the image. So, it can be analyzed by histogram that shows the grayscale distribution in an image Another processing technique is thresholding which is the process of dividing the image into segments. It is used for creating a binary image from a grayscale image.

The output depends on the objective of the application. For example if an object of certain color is to be separated or sorted, after the analysis of the image, a microcontroller is activated to sort the object. The microcontroller is connected to the machine vision system. When the system identifies that color, the microcontroller is initiated to sort it.

1.3 Literature Review

Several articles are available in open literature about the use of vision systems in object recognition and sorting operations in industry. Following are some of the literature in this regard.

Pourdarbani *et al.* [1] presented a study on an automatic sorting system for date fruits based on different stages of its maturity to meet consumers' demands. The framework embodied a conveyer belt on which the dates were passed and a cam to catch the picture of the dates. The sorting framework was a suitable actuator driven by an engine.

Hanmei et al. [2] presented a way of identifying and sorting aquatic products based on machine vision. Machine vision was used to detect the visual quality of fishes, fish filets and some other aquatic products (i.e. shrimp, oyster, and scallop)

Zhang et al. [3] presented a vision based control strategy to do pick and place tasks. CCD camera was used to take pictures every time the conveyer moves a small distance. After picture preparing of the photos, position and states of items was dead set and target following technique was utilized to do sorting operation.

Edinbarough et al. [4] presented a vision inspection system interfaced with a robot based on neural network. IC lead defects were detected in line by this method. The vision framework utilized dark scale pictures and a solitary layer neural system database for each of the ICs to be investigated.

Wang [5] presented a review for using vision based sensing of GTAW. This paper focuses on the researches on weld pool state sensing: conventional sensing technologies, vision sensing technology, and multi-sensor information fusion technology, with giving emphasis on the analysis of three dimensional vision sensing methods.

Wei et al. [6] presented an automatic extraction method of fruit object using machine vision. The method was based on improving threshold algorithm using a new feature in OHTA color space. The organic product articles were naturally removed with this strategy and the yields were demonstrated as binary pictures.

Shafiee et al. [7] presented a report on the development of a computer vision system (CVS) for non-destructive characterization of honey based on colour and its related chemical attributes such as ash content (AC), antioxidant activity (AA), and total phenolic content (TPC).

Kim et al. [8] presented vision-based system for monitoring block assembly. The system consists of segmentation, identification and estimation units. The pictures gained from the camera are at the same time transformed and the areas of the blocks were separated. The extracted blocks were identified and compared to the CAD data to estimate the assembly progress.

Lin and Chiu [9] proposed a machine vision based system for detecting minute flaws occurring in the domed surfaces of LED epoxy-packing. Grey relational analysis was connected to the recurrence segments in piece discrete cosine change area.

Chmiel et al. [10] presented the use of a vision system for estimating fat content in poultry meat. Chicken and turkey bodies were chosen arbitrarily and Analysis was made between substance of white spots procured with vision framework and fat substance decided by using the reference Soxhlet method.

In spite of several above works, still there are requirements to identify the parts moving on conveyors in industries in very effective manner and in short time.

1.4 Objectives of present study

Present study deals with the development of a GUI program in LabVIEW to identify objects with varying attributes such as color, shape and size. Essential objectives of the work include:

1. Using a vision camera, the flowing objects in a conveyer belt are to be recognized and displayed as indicators with part count index.
2. Attributes including size, shape along with colour is to be recognized with various image processing tools including edge detection, pattern matching, etc.
3. Development of the backend G program so as to provide an interactive front panel for the user.

Chapter 2
Object recognition using Machine Vision

This chapter deals with the object recognition procedure with machine vision system.

2.1 Pattern matching

Pattern matching is a simple way of identifying the color as well as shape of the object. In this method, first image is captured from the camera, and then a part of the image to be identified or located is highlighted and saved as a template in .png format. When the vision system runs, and images are being captured and processed, the vision system searches for the aforesaid template in the entire part of the newly acquired image or a region of interest in the image provided by the user. As soon as the template is found i.e., the pattern is matched; the sorting system takes the necessary action.

Pattern matching process comprises of two steps: learning and matching. In learning stage, the vision system extracts the gray value from the saved template and stores it in a way so that it is quickly available at the time of searching or inspection. Matching stage of the algorithm finds matches in the newly acquired image (for inspection) where the pattern matches with highest cross correlation. Tree patterns are used in some programming languages as a general tool to process data based on its structure. Pattern matching is a significant machine vision tool.

Types of pattern matching:

- Guarded pattern matching
- Structural pattern matching
- Heuristic pattern matching
- Ordered pattern matching

Fig-1 shows the pattern matching process with the top left pattern as a template. Others are marked in green blocks.

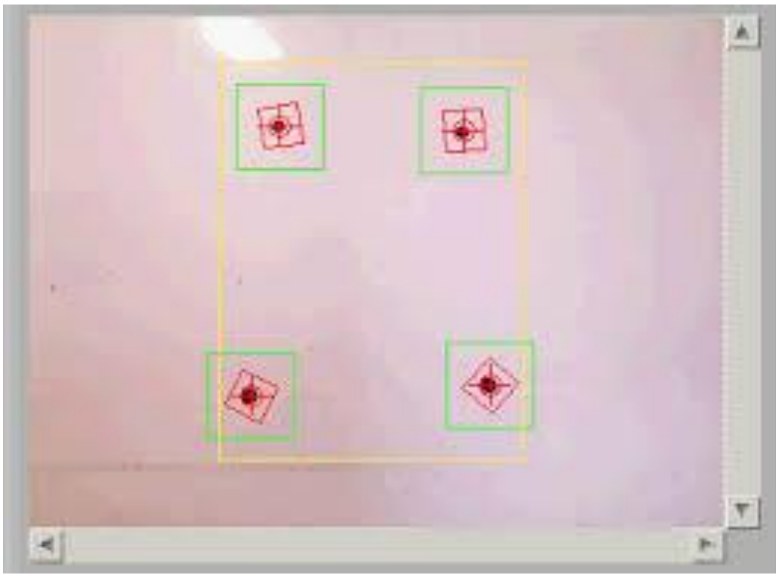


Fig-1: pattern matching

2.2 Edge detection

Edge detection is another way of identifying shapes and sizes. After the image is captured, the machine vision system searches the entire picture or a region of interest for edges based on the different level of pixel intensities. If we maintain a uniform background, the pixel intensity of the entire image will be the same. When an object appears on the vision space, a region of the background is occupied by the object and thus the pixel intensities now are not same. The region where the object is present has different pixel intensity. Taking the advantage of this difference , edges around the object can be detected and utilized in determining size, shape, area and other visual parameters of the object. The four steps of edge detection are: smoothing (filtering noise) , enhancement (sharpening of image), detection (determining which pixel to discard and which to retain) and localization (determining exact location of an edge).

There are various masks used in edge detection. They are:

- PREWITT OPERATOR: Prewitt operator is utilized for distinguishing edges horizontally and vertically.
- SOBEL OPERATOR: The sobel operator is same as Prewitt operator. It is furthermore a derivate cover used for edge acknowledgment. It furthermore figures edges in both horizontal and vertical ways.
- ROBINSON COMPASS MASKS: This operator is also known as direction mask. In this one mask is taken and pivoted in all the 8 major headings to ascertain edges in every course.
- KIRSCH COMPASS MASKS: Kirsch Compass Mask is also a derivative mask which is used for finding the edges. Kirsch mask is used in calculating edges in all the directions.
- LAPLACIAN OPERATOR: Laplacian Operator is also a derivative operator which is used to find edges in an image.It is a second order derivative mask. It can be further partitioned into positive and negative.

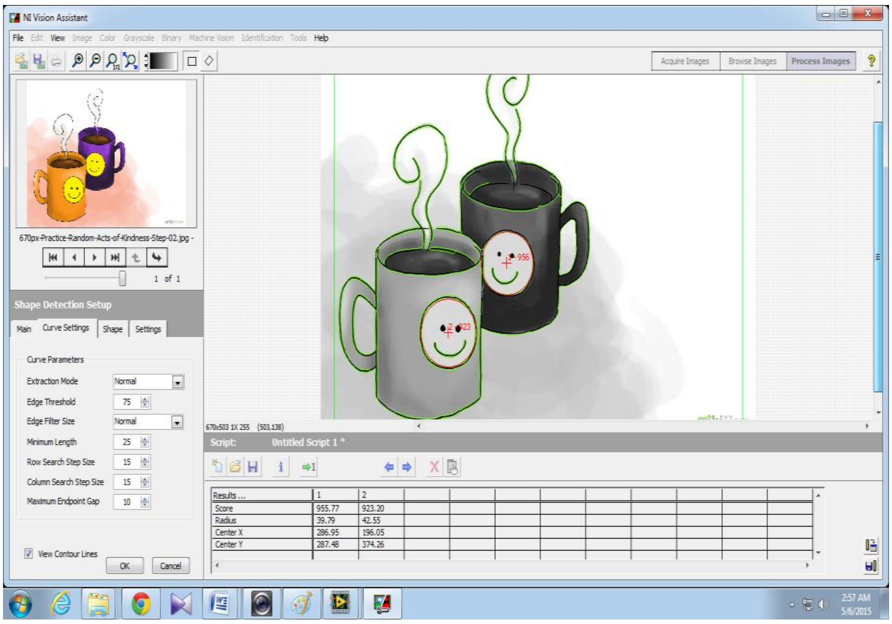


Fig-2: Edge detection in vision assistant

2.3 Geometric matching

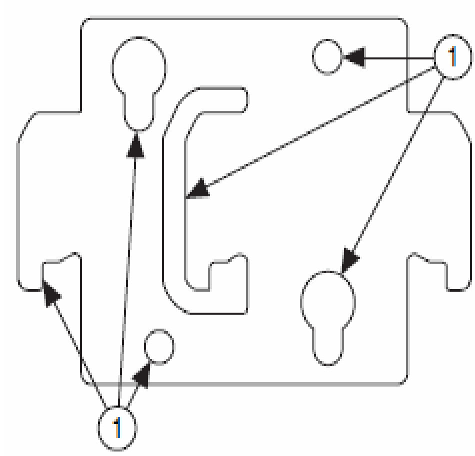
In this method, shapes can be identified properly by matching a certain geometric pattern. Just like in pattern matching, after a picture of the object is taken, a part of the image is saved as template. But in this case the geometric pattern of the object is saved. When the vision system runs, other images are taken and the geometric pattern is searched by the vision system in entire image or in the region of interest. Thus shapes like, rectangle, triangle, square, oval, circular, elliptical, etc can be identified to take the necessary action by the sorting system.

NI Vision includes two geometric matching methods. Both geometric coordinating methods depend on bends extricated from picture to perform the coordinating. The two geometric matching techniques vary in how the bend data is utilized to perform the coordinating.

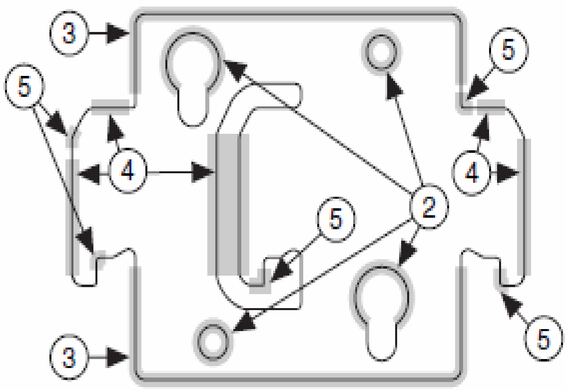
The **edge-based geometric matching method** extracts the gradient value of the edge at each point along the curves found in the image and uses this value and the position of the point from the center of the template to perform the matching.

The **feature-based geometric matching method** extracts geometric features from the curves and uses these geometric features to perform the matching.

Fig. 3 shows the information from the template image that the geometric matching algorithm may use as matching features. Figure A shows the curves that relate to the edges in the template image. These curves form the information that is used by edge-based geometric matching technique. Figure B shows higher level of shape features that the feature-based geometric algorithm utilizes in matching.



(A)



(B)

Fig-3 Geometric matching(1Curves,2Circular Features, 3 Rectangular Features, 4 Linear Features ,5 Corners

Chapter 3

Implementation through LabVIEW

LabVIEW (short for Laboratory Virtual Instrument Engineering Workbench) is a system-design platform and development environment for a visual programming language from National Instruments. The graphical language used is named "G". The programs written in LabVIEW are called VIs. LabVIEW programs can be integrated easily with most hardware with installed drivers in the computer.

3.1 LabVIEW software basics

LabVIEW consists of two windows called front panel and block diagram.

Front panel

Front panel of the LabVIEW environment is where the GUI so developed is seen. The GUI will have the same appearance and environment as that of the front panel. Front panel consists of number of grids. The front panel consists of tools like run , pause, stop, etc. These tools help in starting and stopping the program. The control toolbar consists of various option like modern, classic, express, control design and simulation, signal processing, add ons, user controls, etc.

When you open a new or existing VI, the front panel window of the VI appears and functions as the graphical user interface or GUI of a VI. You can find the source code that runs the front panel on the block diagram. The front panel window contains a toolbar across the top and a controls palette that can be accessed by right-clicking anywhere on the front panel. In summary, front panel is the window where different controls (switch, knobs, numeric inputs) and indicators (graphics, LEDs) can be viewed. Fig. 4 shows the screen shot of front panel with control palette and indicators.

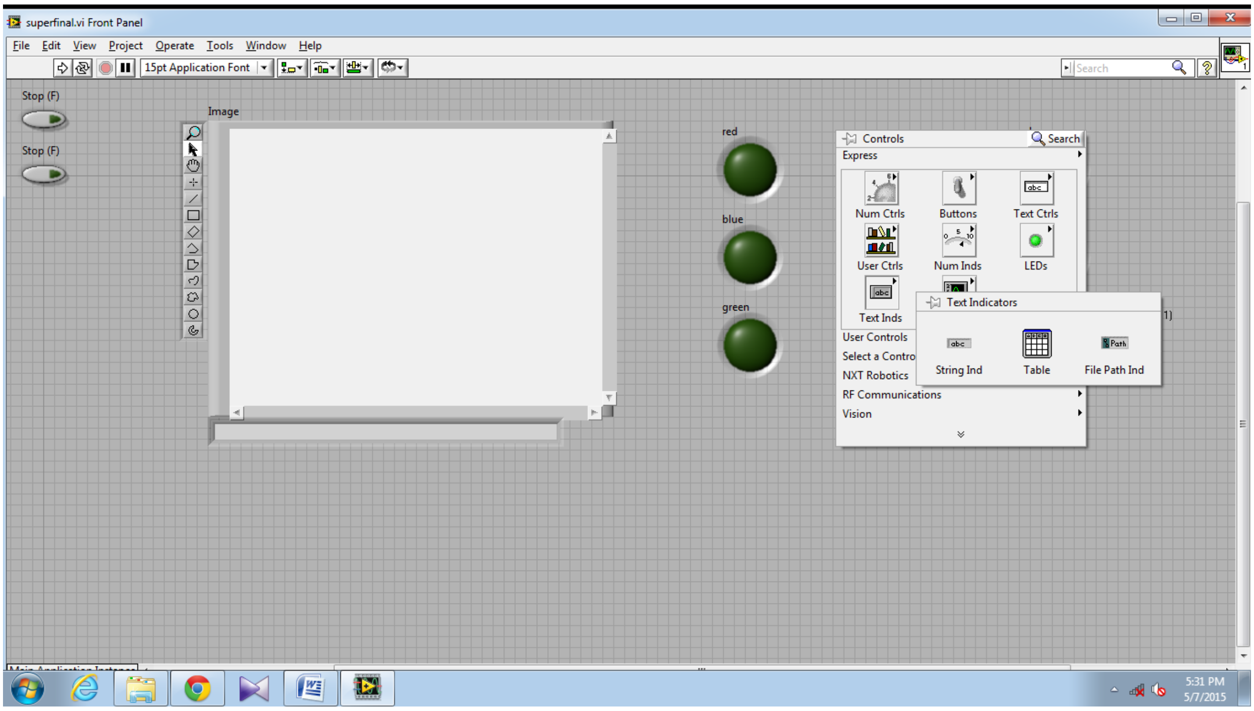


Fig-4: front panel with controls palette

Block Diagram

Block diagram is where all the programming part exists. It consists of function palette where there are options like programming, measurement i/o, system i/o, mathematics, vision and motion, data communication connectivity, etc. All the programming is done in this part of LabVIEW, where the codes are written in the form of block diagrams. All inputs and outputs are wired in the block diagram. Block diagram include terminals, subVIs, functions, constants, structures, and wires that transfer data among other block diagram objects or blocks. LabVIEW tools can be used to create, modify, and debug a VI. A tool is a special operating mode of the mouse cursor, so the operating mode of the cursor corresponds to the icon of the tool selected. LabVIEW chooses which tool to select based on the current location of the mouse. Tools can be chosen manually by selecting it on the Tools menu. Block diagram consists of different functions like mathematical, Boolean and programming loops. Fig: 5 shows the screen shot of block diagram with function palette.

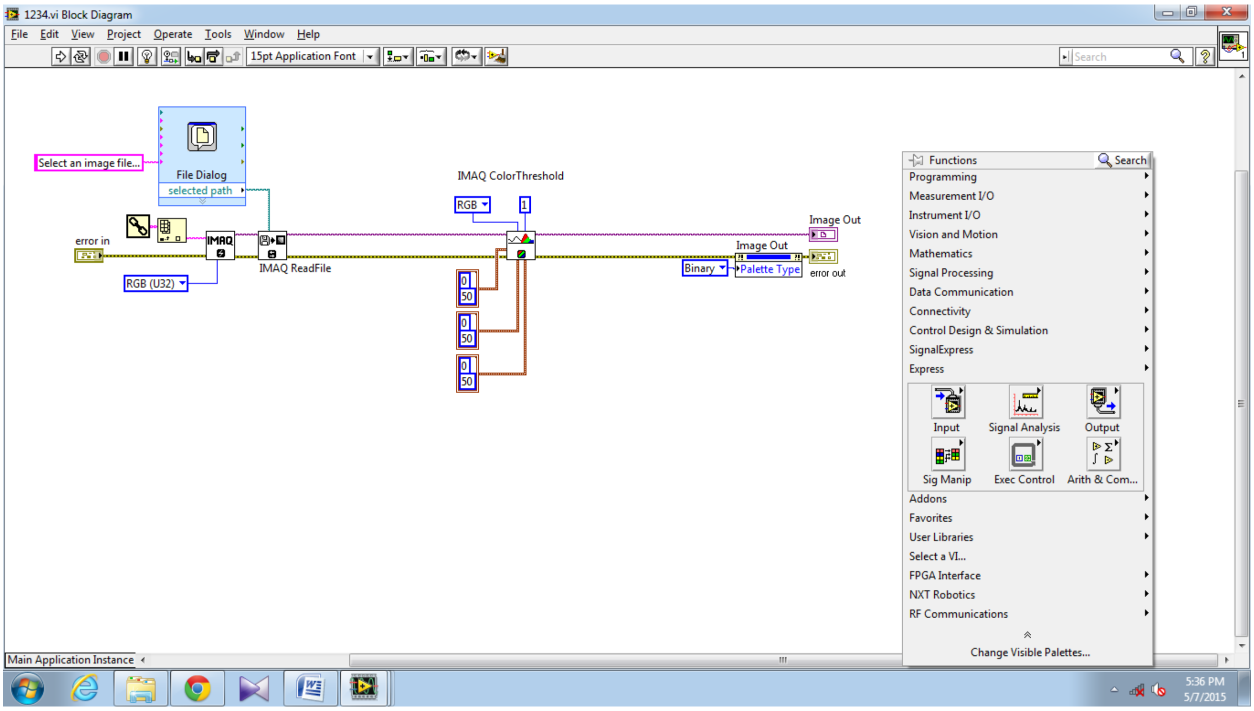


Fig-5: block diagram with functions palette

Express VIs (eg: simulate signals) can be used to simulate signals etc. Similarly filtering express VI is used to filter the noisy signals. NI vision is a library included in the development module for LabVIEW. NI vision is meant for development of machine vision and scientific imaging.

Several applications are found on the LabVIEW utilization in engineering sciences. Chandramohan and Marimuthu [11] presented the implementation of LabVIEW, in a bending of beam experiment to allow the acquisition of real time data for display, analysis, control and storage. The aim of the paper is to control and apply moment to a beam, and collect data from the resulting deformation in the material. Wang et al. [12] presented the design and implementation of a data acquisition program using LabVIEW for a liquid crystal tunable filter based spectral imaging system (900–1700 nm). The module-based program was designed in a three-tier structure. Wang et al. [13] presented a LabVIEW based automatic test system for Complementary Metal Oxide Semiconductor (CMOS) chips that are smaller in size and power consumption with multifunction in order to reduce the workload of the engineer, improve the testing efficiency and accuracy.

Vision assistant

Vision assistant is another module in National Instruments where image obtained from the camera can be processed as per the requirement. Vision assistant consists of several tabs for processing images under different functions like colour, grayscale, binary, machine vision, etc LabVIEW vi can be generated by a series of algorithms written in vision assistant and vision assistant can be opened using a block diagram in LabVIEW. Vision assistant can prove to be very effective and time saving in processing images. If only LabVIEW is used, image processing can be complex and tedious. Fig:6 shows screenshot of vision assistant window.

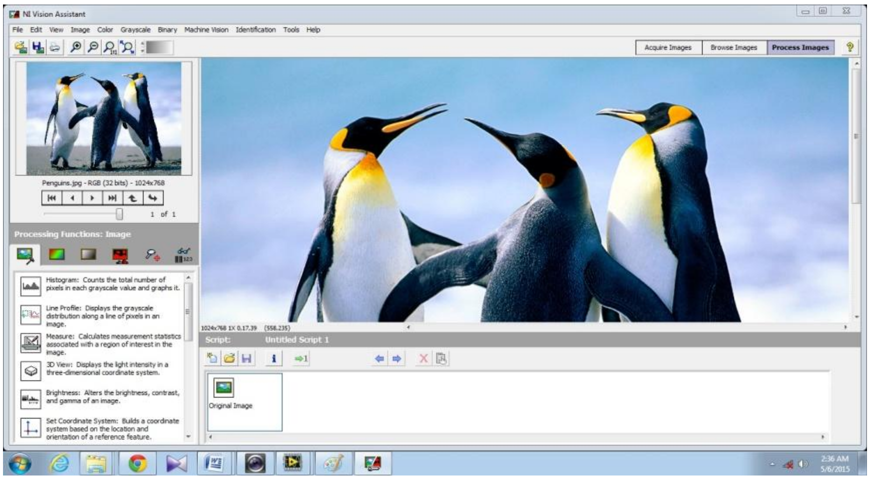


Fig-6: vision assistant window

3.2 LabVIEW vision system

This section explains process of image acquisition, image analysis and output display obtained in the present work.

Image setting

In order to consider the objects with varying attributes, a small wooden models were constructed with varying parameters : colour (red, blue and green) , shape (triangular prism and cuboid) and size (large and small). These blocks were allowed to pass through a conveyor system. The image was captured continuously by a camera. The background of the setting was kept plain white so that objects can be detected properly. Illumination was provided by using a fluorescent lamp. Fig:7 shows the sample objects used in the present work.

Fig-7: objects for demonstration

On the basis of color, three types of objects were used for demonstration; red, blue and green. On the basis of shape two types are to be separated: triangular and rectangular and on the basis of shape large and small.

Camera

Webcam of 1.3 megapixels inbuilt in Dell inspiron 5050 was used in capturing the images of various objects. The resolution of the camera was fine enough to detect colours, shapes and sizes accurately. The driver used was dell webcam central.

Image analysis

Once the images of various objects were acquired by the camera, processing was done by the vision system in vision assistant. Colours were identified by the process of colour location. This process is like pattern matching but for colours. A template of different colours were already saved as .png file. Comparing the newly acquired image of the objects with the saved template, colours were identified as red, blue and green. Shapes were identified by the process of geometric matching in vision assistant. Same as before templates were saved in .png file for different geometric shapes and the new images were compared and identifies as triangular and rectangular. Size was determined by using edge detection in vision assistant. While acquiring images in a continuous manner, vertical straight edges of the objects were located in the images by using clamp distance feature in vision assistant. By calculating the calibrated distance in pixels and giving a threshold value, the size of the objects were determined as small and large. The threshold calibrated distance was given as 100 pixels. If the distance between the edges were smaller than this value the object was considered as small, and large if greater.

Output

Output was provided by glowing indicators (LEDs) in LabVIEW GUI. Three LEDs were provided for colour(red, blue and green), two for shape(prism and cuboid) and two for size(large and small). Whenever a red object was identifies the LED with label red glows. Similarly for shape and sizes identified respective LEDs glows to give the output. Also the number of objects of a particular color (red, blue, green) and particular shape (triangle, rectangle) were counted and the efficiency of the vision system was discussed.

Conveyor belt system

A motor driven conveyor belt system was fabricated to transport the wooden objects. The other end is carried on a shaft mounted on a ball bearing system. The approximate speed is 0.028 m/s. The power supply was provided by a 9v battery.

Motor specification: 12v, 10 rpm Fig: 8 shows a conveyer belt system used in the process.

Fig-8: conveyor belt system

3.3 The proposed approach

When the program was run, continuous images were captured by the camera. The images were processed and looked for each color pattern(red, blue and green) by the method of colour location in vision assistant. If a certain color match was found the number of matches were counted and displayed and respective LEDs glow if the number of matches was greater than or equal to 1. After color identification, the 32 bit RGB image was converted into 8 bit image and geometric pattern match of that image was carried out in vision assistant. Template images for rectangular and triangular pattern were saved before the start of the program. In the 8 bit image if triangular pattern was found the number of matches were displayed and respective LED glows whenever the number of matches was more than or equal to 1. Same was done for rectangular pattern match. In other path, the 8 bit image was processed and horizontal edge to edge distance was calculated by the *clamp* function in vision assistant. If the calibrated distance was more than 100 pixels the object was determined as large and respective LED was glowed. If the calibrated distance was in range of 1 to 100 pixels, the object was determined as small and respective LED glows.

Fig: 9 shows flowchart of the identification methodology.

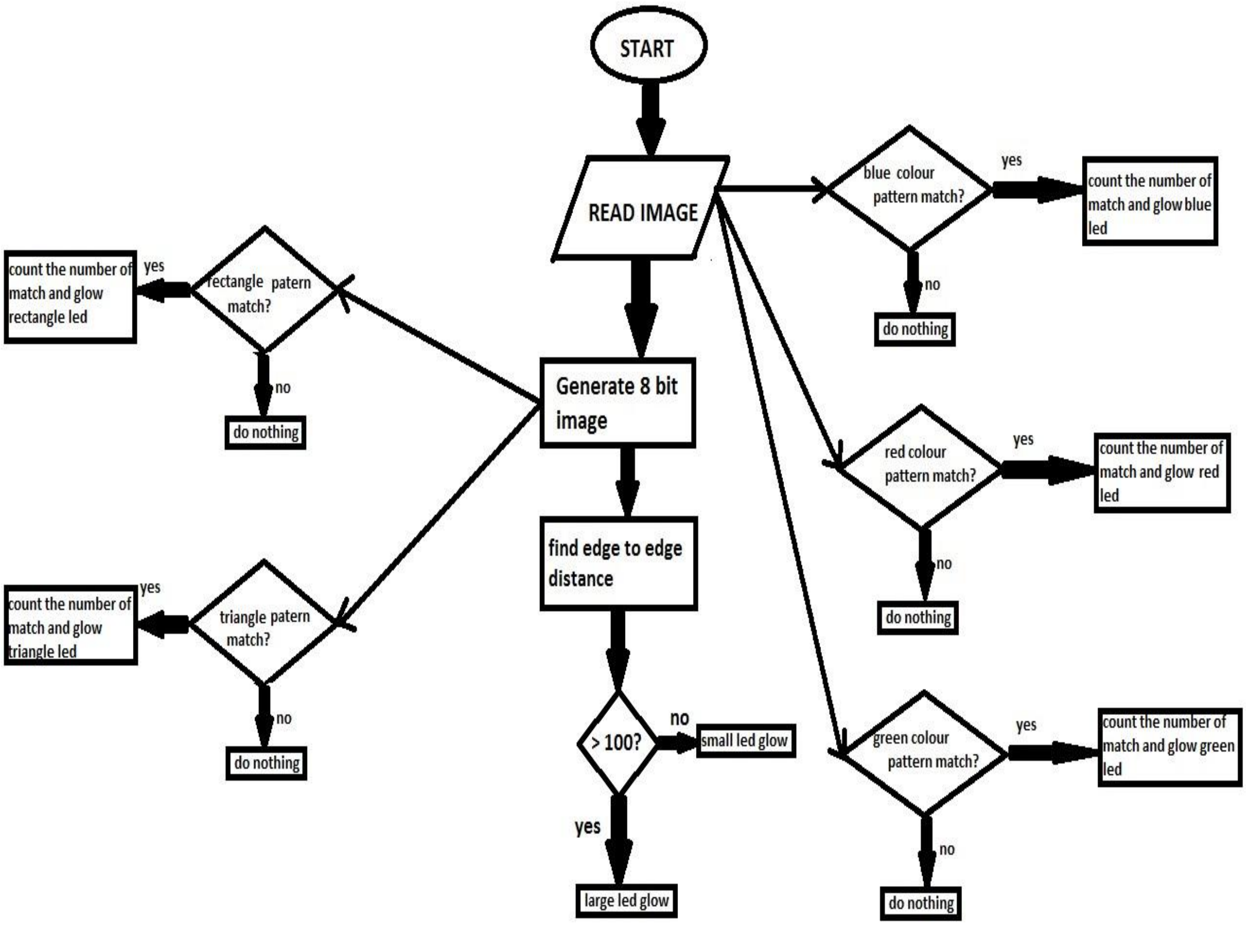


Fig-9: Flowchart of the program

Color recognition is based on RGB model in which a range of red, blue and green layers are used to identify the objects by scanning the image for each defined color. A binary mask is then created for each colored object. The image is preprocessed by suppressing the background. The generated binary mask is then used to determine other properties of objects like size and shape. The size of object is estimated by finding the area (counting the number of pixels in the mask).

Based on the above flowchart, a VI is developed to count and indicate the different objects moving on the conveyer belt. Fig:10 shows the block diagram of the VI.

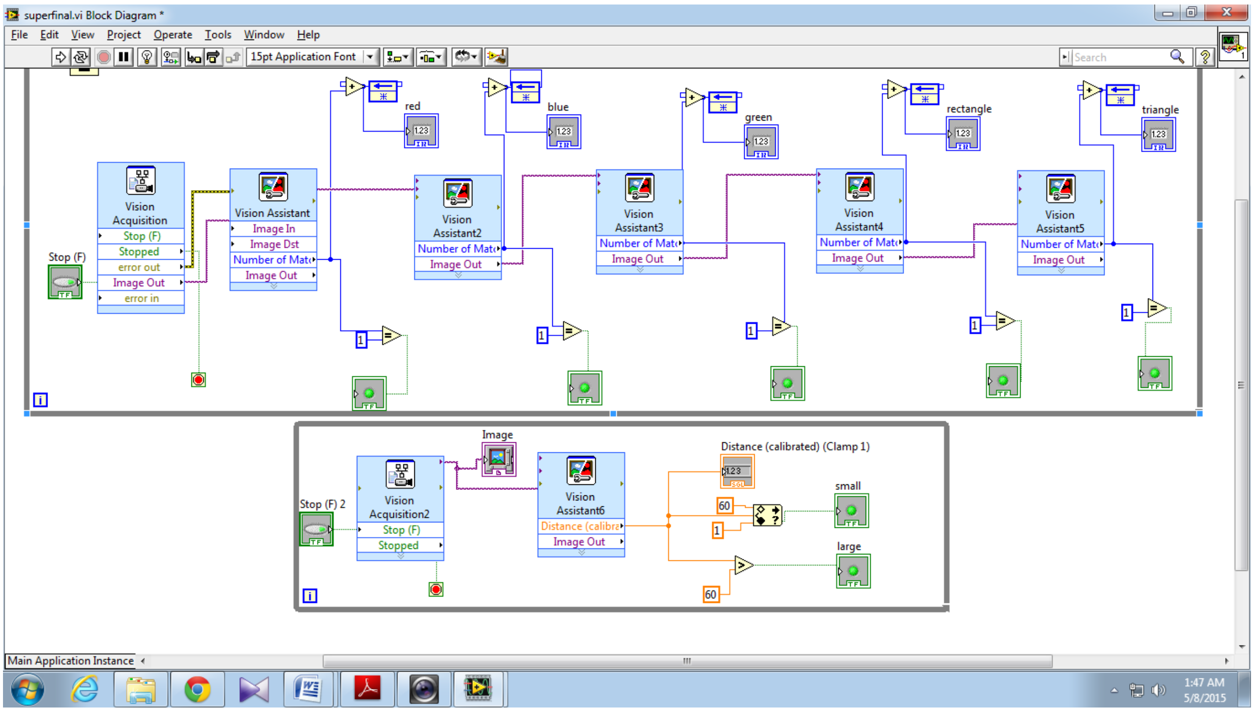


Fig:10 block diagram of the part identification approach

As seen in the figure, the vision acquisition block acquires the image and vision assist block processes the image and the object identification can be done in steps mentioned as per the present logic.

3.4Outputs and discussions

Three trails were conducted for demonstrating the work of the GUI. Fig-11 shows the output while first object is passing through the conveyer. As shown by the glowing LEDs and the counting boxes, the parameters were detected for *large blue* colored object with *triangular* shape. The parameters of the second object was also detected correctly.

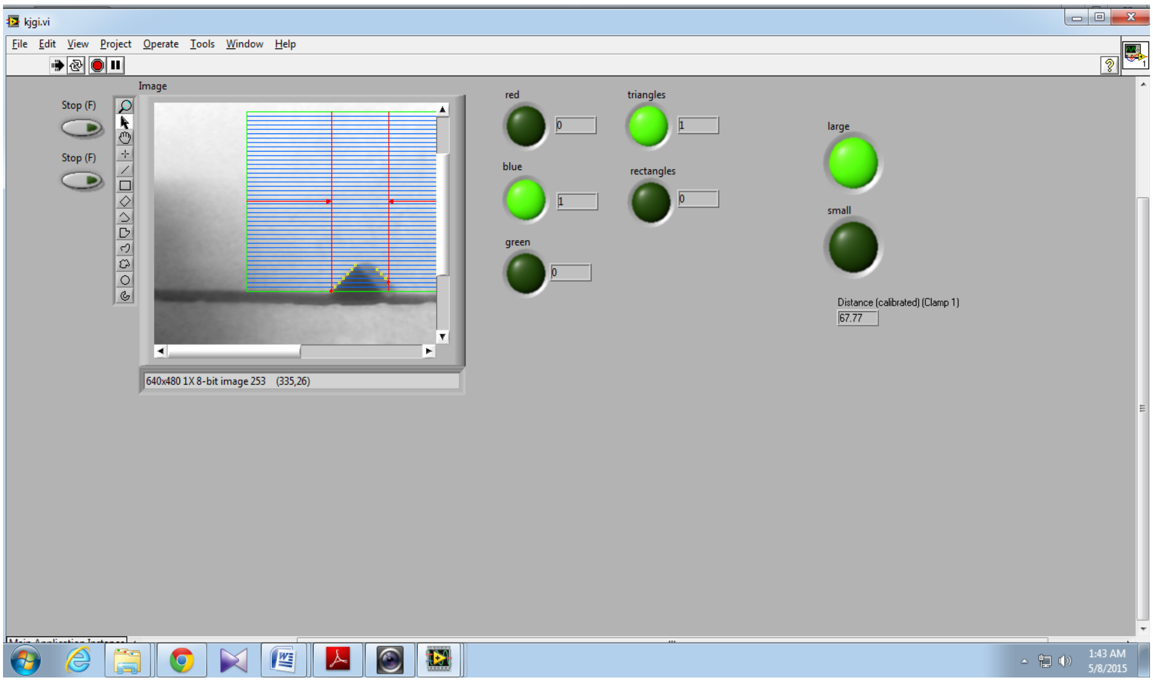


Fig-11: Output window displayed in the front panel

Fig-12 shows the output in the front panel with the object as small green one with rectangular shape. The size of the object being large or small was detected by calculating the edge to edge distance. A threshold value of 100 pixels was given. If the calibrated distance was less than this value the object was shown as small by a glowing LED labeled ‘small’ else it was shown as large. The process of identification can be continued for any number of objects passing dynamically in the field of view of camera. The trails with different number of objects is explained next.

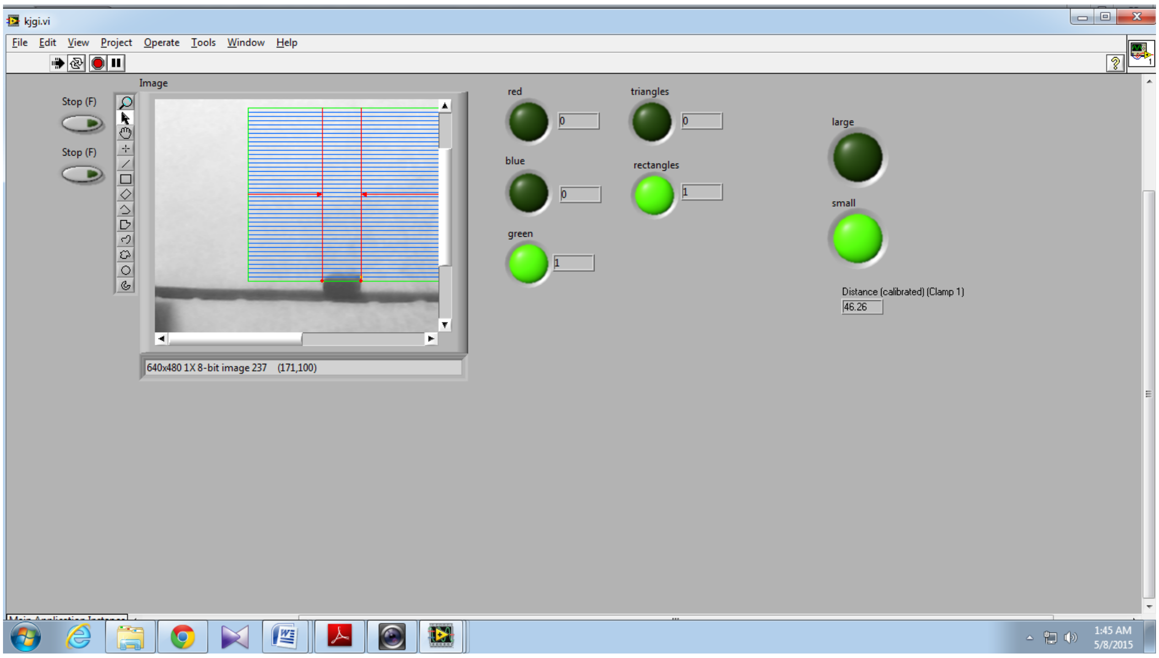


Fig-12: Output displayed in the front panel

The results of three trails conducted by passing a number of objects in the conveyer are shown in tables. Table -1 shows the result of the first trail that considers 5 objects. One rectangular shape was unable to be identified by the vision system and other parameters were detected accurately.

Table-1 Results of identification in Trail-1 (Total 5 objects)

colour	actual	detected	Shapes	Actual	detected
Red	2	2	Rectangle	2	1
Blue	2	2	triangle	3	3
green	1	1			

Table-2 shows the results of the second trail, where 6 different objects are considered. Two shapes were not detected in this trail. Other parameters were detected properly.

Table-2 Results of identification in Trail-2 (Total 6 objects)

Color	actual	detected	shapes	Actual	detected
Red	1	1	rectangle	3	2
Blue	3	3	triangle	3	2
Green	2	2			

Table-3 shows the results of the third trail. In this trail, red colour of one of the objects was not detected properly but all the other parameters were fine.

Table-3 Results of identification in Trail 3 (Total 7 objects)

Color	actual	detected	shapes	Actual	detected
Red	1	2	Rectangle	4	4
Blue	3	3	triangle	2	2
green	3	3			

In overall sense, the objects were identified accurately on the basis of shape, size and colour. But some errors were encountered due to the improper lighting, resolution of camera and randomness while passing on the conveyor. Sorting system must require adequate illumination to detect the parameters perfectly. Bad lighting may cause improper image acquisition and thus undesired output. This system can be very effective in production industries. LabVIEW is found to be very user friendly in developing the GUI. Since it has block diagrams for every codes and loop structures, complexity of writing codes as well as probability of error in syntax is highly reduced.

Chapter 4

Conclusion

In this work, the vision system has been employed for identification of objects in terms of their attributes including color, shape and size. An interactive graphical user interface was developed in LabVIEW with Vision assistant module. The user can observe the field of view along with the part count in each category. Further the front panel identifies the shapes including rectangle and triangle with an LED indicator. Likewise, small and large shapes can also be distinguished. The camera's ability to separate the noisy colors is a prime factor in this analysis. Also, the program has ability to identify the other colors as well as more number of shapes.

In real practice, the industry requires parts separation as per the attributes described above and we can employ some actuation mechanism to separate the objects as per the signal received from the vision system. For this a microcontroller interfacing is needed and this may be considered as a future work.

References

[1]. R.Pourdarbani H. Ghassemzadeh, H. Seyedarabi, F. Nahandi, M. Vahed, Study on an automatic sorting system for date fruits, Journal of the Saudi Society of Agricultural Sciences, vol.15, pp. 83-90, 2015.

[2] Hanmei Hong, Xiaoling Yang, Zhaohong You, Fang Cheng, Visual quality detection of aquatic products using machine vision, Aquacultural Engineering, vol.63, pp. 62-71, December 2014.

[3] Wenchang Zhang, Jiangping Mei, Yabin Ding, Design and Development of a High Speed Sorting System Based on Machine Vision Guiding Physics Procedia 25, pp. 1955-1965, 2012.

[4] Immanuel Edinbarough, Roberto Balderas, Subhash Bose, A vision and robot based on-line inspection monitoring system for electronic manufacturing Computers in Industry 56, pp. 986-996, 2005.

[5] Xuewu Wang, Three-dimensional vision-based sensing of GTAW: a review Int J Adv Manuf Technol 72, pp. 333–345, 2014.

[6] Xiang Wei, Kun Jia, Jinhui Lan, Yuwei Li, Yiliang Zeng, Chunmei Wang, Automated method of fruit object extraction under complex agricultural background for vision system of fruit picking Optik, international journal for light and electron optics, vol. 125, pp. 5684-5689, 2014.

[7] Sahameh Shafiee, Saeid Minaei, Nasrollah Moghaddam-Charkari, Mohsen Barzegar, Honey characterization using computer vision system and artificial neural networks Food Chemistry,Volume 159, pp.143–150, 2014.

[8] Minsung Kim, Woosung Choi, Byung-Chul Kim, Hokyeong Kim, Jae Hun Seol, Jonghun Woo, Kwang Hee Ko, A vision-based system for monitoring block assembly in shipbuilding, Computer-Aided Design Volume 59, pp.98–108, 2015.

[9] Hong-Dar Lin, Singa Wang Chiu, Flaw detection of domed surfaces in LED packages by machine vision system, Expert Systems with Applications Volume 38, Issue 12, November–December 2011, pp.15208–15216.

[10] Marta Chmiel, Mirosław Słowiński, Krzysztof Dasiewicz, Application of computer vision systems for estimation of fat content in poultry meat Food ControlVolume 22, Issue 8, pp.1424–1427, August 2011.

[11] D. Chandramohan and K. Marimuthu , Application of LabVIEW on Material Testing (International Journal of Engineering Studies, Volume 3, Number 2,pp. 87-94, 2011)

[12] Weilin Wang, Changying Li, Ernest W. Tollner, Glen C. Rains, Development of software for spectral imaging data acquisition using LabVIEW, Computers and Electronics in Agriculture Volume 84, pp.68–75, June 2012.

[13] Z.Wang, Y.Shang, J.Liu, X.Wu, A LabVIEW based automatic test system for sieving chips, Measurement, Volume 46, Issue 1, pp.402–410, January 2013.

Web references

http://www.tutorialspoint.com/dip/Concept_of_Edge_Detection.htm

http://en.wikipedia.org/wiki/Edge_detection

http://www.generation5.org/content/2002/im01.asp

http://zone.ni.com/reference/en-XX/help/372916P-01/nivisionconcepts/geometric_matching_technique

http://en.wikipedia.org/wiki/LabVIEW

http://www.ni.com/white-paper/7566/en/

http://www.ni.com/tutorial/7565/en/

http://zone.ni.com/reference/en-XX/help/371361J-01/lvconcepts/blockdiagram/